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Distributional and Environmental Effects of Taxes on Transportation

Abstract:
This article studies environmental and distributional effects from a differentiated tax system on a set of disaggregated transportation goods. Empirical examination on Norwegian data indicates that higher tax rates on high-pollution luxury modes of transportation such as air flights and taxis reduce inequality and increase the environmental quality. Lower tax rates on low-pollution necessary modes such as buses, bicycles, and mopeds reduce inequality and increase environmental quality. However, higher taxes on high-pollution necessities such as gasoline have favorable environmental effects, but increase inequality somewhat. Railway passenger transportation appears to be distributionally neutral. In order to interpret the estimates with respect to distributional and environmental concerns, we use a theory of distribution effects based on Engel, child, and adult elasticities and a wide range of empirical estimates of environmental hazards from transportation consumption. For different modes of transportation, we study emissions per passenger-kilometer and per monetary unit.

Keywords: Distribution, environmental effects, indirect taxation, Pigou correction, transportation

JEL classification: D12, D31, H23, R41

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1. Introduction

Taxes on polluting goods can enhance environmental quality by reducing the consumption of those goods, an insight modeled by Pigou (1920) – hence the name Pigouvian taxes. By intervention in the price mechanism a policymaker may correct for externalities that escape the cost internalization in the market place. At the same time, such taxes will affect different households differently since the consumption pattern varies with income and demographic composition. While correcting for environmental damage, some levies on consumer goods lead to more inequality, others to less inequality. This article addresses the issue of distributional effects of environmental taxes. More specifically, since some modes of transportation are both luxury items and high-polluters and other modes are necessities and low-polluters we argue that is possible to have favorable environmental and distributional effects by implementing a differentiated tax system. To demonstrate the empirical content of our argument and to illustrate its policy relevance, we obtain empirical estimates on consumer behavior and a range of environmental effects of transportation.

In practice it is difficult for policymakers to know exactly the optimum magnitude of a correction because it presupposes knowledge about the severity of the impact that the externality represents. This problem has yielded a large literature on the policy choice of price incentives versus quantity control; see Weitzman's (1974) seminal article. As a consequence of the paucity of unambiguous advice, policies often adopt quite general schemes, at best based on a combination of analysis and intuition. The problem of finding taxes that correct for the gap between private cost and social cost becomes especially acute when researchers and policymakers realize the potential urgency. Possibly, irreversible processes and ecological sustainability issues do not leave society with the luxury of having a sufficient amount of time to compute the taxes accurately. Another issue is that optimum Pigouvian taxes combined with distributional lump-sum transfers are not available. In the theory of second-best solutions, Sandmo (2000) encourages investigators to consider the simultaneous effects of Pigouvian taxes on the environment and the distribution of consumption. Policymakers implement broad tax schemes aimed at wide targets and the distributional concerns of such schemes have come under scrutiny. Here we show how a general environmental tax on a large category of goods will be less effective environmentally and distributionally than will a differentiated tax system on specific goods within that category. This follows from a dichotomy in which the more polluting goods are luxuries and less polluting goods are necessities. Opposite combinations do occur, and with them resulting conflicts between environmental and distributional effects arise.

This article documents the tax system's dual effects on the environmental quality and the distribution by empirical scrutiny and econometric estimation. We present a simple theory for how observers can assess distributional effects in tandem with the potential environmental corrections. Moreover, we estimate Engel, child, and adult elasticities for many transportation goods and employ them as distributional indicators. In order to do so, we use a simple theory that explains why the elasticities are such indicators. Using several sources, we present supplementary environmental indicators of the same modes of transportation. Combining the two sets of indicators, we are in a position to investigate a potential double dividend of obtaining favorable environmental and distributional effects from the same, differentiated tax system.

A clear empirical pattern of consumption emerges from our data. Households with a low material standard choose the least expensive alternatives among goods and services that satisfy certain transportation needs. Examples are buses, bicycles, and mopeds. In order to satisfy much the same needs, richer households choose more expensive qualities among the class of goods and services that deliver what is demanded. Examples are air flights, automobiles, and taxis. Environmental indicators suggest that luxuries are in fact more polluting than necessities, hence the double dividend. A tax on railway passenger transportation is distributionally neutral, but may still serve as an externality correction. However, while higher taxes on gasoline appear to have favorable environmental effects, they will increase inequality somewhat. Thus, the transportation good gasoline appears not to offer any potential for a double dividend.

The idea of a double dividend has been much debated in economics, although not on the pair consisting of environment and inequality. Rather, the focus of attention has been on the pair environment and tax efficiency. The idea has been that by using one instrument a policymaker can attain two goals, both increasing tax revenue and improve environmental quality. Increasing tax revenue is beneficial because it relieves the pressure on other efficiency-distorting taxes. Recent research has uncovered problems with the idea; see Bovenberg and de Mooij (1994). The ensuing debate over double-dividend, see e.g. Goulder (1995), revealed the interest for combined aspects of taxation and the environment. Moreover, researchers are also highly interested in another aspect of environmental taxation: the effect on distribution, see Prooost and van Regemorter (1995), Mayeres and Proost (1997), and Sandmo (2000). As de Mooij (1999) states, "distributional issues, rather than efficiency, often dominate the political discussions about environmental policy instruments". Sandmo points out the benefits of considering environmental policy in conjunction with society's general policy of redistribution. In this article we examine exactly that conjunction.

We present findings that have relevance to policymakers. The theory we present shows that if a policymaker wants to support households with small total consumption in contrast to households with large total consumption then a well-designed equity policy includes large taxes on goods with high Engel elasticity and small taxes on goods with low Engel elasticity. If the policymaker wants to support households with children in contrast to households without children the theory shows that an equity policy includes large taxes on goods with low child elasticity and small taxes on goods with high child elasticity. Budget shares and elasticities are computed by using regression analysis on the Norwegian Consumer Expenditure Surveys for 1986-1994. The estimates are obtained by using a parsimonious two-stage-least-squares econometric model with income as instrumental variable and by having (latent) total consumption, number of children, and number of adults as regressors. We present and use the averages of the period.

The next section illustrates the underlying principles of the idea that there is a distribution effect from a tax on a consumer good by presenting a simple model for distribution. In the subsequent section we present, empirically, the distributional effects of indirect taxation and discuss the main consumption patterns of broad categories. We include definitions of the elasticities, explain the use of elasticities as empirical indicators, and show their potential as distribution instruments in policy. In section four, we go on to present results on detailed disaggregated transportation goods. We document the Engel, child, and adult elasticities for the transportation consumption, and discuss the major findings. Section five examines the environmental effects and characteristics of taxes on specific subcategories within the class of transportation. Section six discusses political implications and makes concluding remarks. An appendix describes the data set and the empirical methods we employ.

2. Policy Indicators of Consumer Behavior

Let us illuminate the coexistence of distributional and environmental concerns by introducing a simple model that explains the principles. Imagine an economy in which there are two types of households, rich and poor. Let there be six types of transportation modes in the economy. The modes may be categorized into classes of inexpensive and expensive modes of transportation. The class of inexpensive vehicles consists of bus, moped, and bicycle. The expensive class comprises air flight, automobile, and taxi. Let the three types within each class cover the transportation needs that arise. Moreover, let us assume that while poor households attend to their needs of transportation by using the cheap alternatives, rich households satisfy their needs by choosing the expensive alternatives. In this economy, policymakers can redistribute material standard of living between rich and poor by levying taxes on the luxurious means of transportation, used by the rich households, and subsidizing the cheaper means of transportation, used by the poor households. In this case, as is often the case, the cheaper alternatives are necessities and also seems to be the most environmentally friendly, while expensive modes are luxury items and high polluters. Given policy aims, policymakers may implement an indirect tax regime that attains two goals, both an environmental one and a distributional one.

In reality, economies are far more complex. There is no clear distinction between poor and rich households. Rather, there is an approximately continuous joint distribution of income along many different dimensions of household characteristics. Further, households may have different preferences and solve the optimization programs differently. A poor household with many children may find it economical to purchase an old car instead of relying too much on public transportation. Some rich and old single persons would prefer a bus to driving alone. Below, we will introduce a model that can capture different facets of an economy and be employed to analyze actual consumer expenditure data from a representative sample of Norwegian households. We also show how important data information may be condensed into a few interpretable parameters.

In this article, we present indicators for how well suited some consumer goods are for high or low taxes, given that a policy maker is willing to use indirect taxes to make the material standard of living more equally distributed. If the policymaker wants to support households that maintain a low total consumption relative to households that enjoy a high total consumption, ceteris paribus, then she should put high taxes on goods with high Engel elasticity and low taxes (possibly negative) on goods with low Engel elasticity. If the policymaker wants to support households with (many) children relative to households with no children, ceteris paribus, then she should put high taxes on consumer goods with low child elasticity and low taxes (possibly negative) on goods with high child elasticity. These policy goals may or may not coincide with goals set for environmental quality. Below, we shall inspect the relationship empirically.

Consumers pollute through their transportation consumption by using polluting vehicles. In order to assess the environmental impact of transportation consumption, an investigator needs to establish indicators. We rely on three sources of assessment of the environmental impact from consumer transportation. The first two considers different aspects of pollution connected to distances traveled. In other words, the measures amount to relaying emissions per person-kilometer or energy consumed per person-kilometer for specific types of transportation. This indicator captures the idea that commuting by taxi entails different emissions per kilometer than commuting by bicycle. Traveling long-distance by air represents an impact on the environment different from traveling by train. The third source we consider is developed especially for this study. We derive measures of several types of emissions per monetary unit of purchase expenditure. This is a useful measure since taxes will be levied on consumer prices, the idea investigated being that although some modes of transportation may pollute considerably per distance traveled, these modes may also be priced heavily per distance traveled.

The environmental effects are not computed in full. It is nearly impossible to cover all aspects of environmental impact from transportation. Not only does the activity affect the atmosphere, the soil, and the ocean, but transportation also represents visual intrusion, create noise, and occupy space through the establishment of rails, roads, and airports. Here we limit the environmental assessment to the study of discharges like the gases CH_4, CO_2, N_2O, NO_x, NH_3, and SO_2, in addition to energy consumption.

3. Distributional Effects of Indirect Taxation

There are several indicators for how well suited goods are for redistribution purposes through indirect taxation, below we will present three indicators: The Engel elasticity, the child elasticity, and the adult elasticity. A detailed theory giving support to our claim that these indicators are relevant for the purpose at hand is given in Aasness and Røed Larsen (2002). The appendix of the present paper offers an outline of some basic elements of this theory.

The Engel elasticity states how much, in percentage terms, a household changes its expenditure on a good when the total consumption expenditure increases by 1 percent. Table 1 shows that the category food has the lowest Engel elasticity among the main categories in the Norwegian Consumer Expenditure Surveys (CES). Its Engel elasticity is approximately 0.3. It means that when total consumption expenditure increases by 1 percent, then expenditures on food is found to increase by 0.3 percent. In other words, when total purchase expenditures increase the purchase expenditure on food will also increase, but it will increase less than total expenditure, and so the budget share for food becomes smaller as the household grows richer. Thus, food is a necessary good, according to the standard terminology in economics, defining necessary goods as goods with Engel elasticity below unity and luxury items goods with Engel elasticity above unity. The low Engel elasticity of food is an empirical regularity more than a sometimes-seen finding. Because of its consistency over time and over economies it has attained the status of a law, Engel's Law, named after Ernst Engel (1895) who documented the regularity more than a hundred years ago.

From Table 1 we see that the category travel and transportation has a high Engel elasticity, approximately 1.2. Thus, when total consumption expenditure increases by 1 percent expenditures on travel and transportation increase by 1.2 percent. Since the expenditure on travel and transportation increases more than total consumption expenditures, its budget share will increase. We say that travel and transportation is a luxury good. A tax on a luxury good will primarily affect payments from well-to-do households since they spend more, both in absolute and in relative terms, on this good compared to poor households.

The indicator Engel elasticity gives the following mandate to a policymaker: If the goal is redistribution, an adequate scheme is to tax travel and transportation and subsidize food.

The child elasticity measures the change in a household's expenditures on a good when the number of children increases by one, relative to the average expenditure on the good per person. From Table 1 we observe that the child elasticity for food is approximately 0.4. This means that if a household on average has an expenditure on food at 10 000 kroner per person, an increase in the number of children by one would lead to an increase of 4 000 kroner in the purchase expenditure on food. Thus, the expenditure on food increases, as is a natural result when the household becomes larger. Moreover, we see that the travel and transportation good has an associated child elasticity of approximately -0.3. An increase in the number of children would, everything else being equal, lead to a reduction in the expenditures on travel and transportation. In the example mentioned above, the household would reduce its spending on travel and transportation by 3 000 kroner. To see the intuition behind these results, consider the following argument. When the number of children in a household increases the household experiences several effects: First, it becomes poorer in the sense that it has available a smaller amount of disposable income per household member. This income effect pulls in the direction of reduced expenditure on all goods. Second, the size of the household increases. This size effect pulls in the direction of increased expenditure on all goods children uses. Food is characterized by a stronger second effect, while the travel and transportation category is characterized by a stronger former effect.

Table 1. Indicators of Distributional Effects. Total Consumption Divided into 9 Categories. Average 1986-1994. Standard errors in parentheses

Good	Budget share	Engel elasticity	Child elasticity	Adult elasticity
Food	150.57	0.284 (0.037)	0.389 (0.025)	0.727 (0.037)
Beverages and tobacco	36.44	0.957 (0.070)	-0.403 (0.050)	0.049 (0.047)
Clothes and shoes	68.00	1.113 (0.060)	0.263 (0.038)	0.220 (0.047)
Housing, light and fuel	248.83	1.148 (0.062)	0.074 (0.026)	-0.559 (0.040)
Furniture and house equipment	81.85	1.281 (0.078)	0.221 (0.056)	-0.547 (0.068)
Health care	21.91	0.723 (0.132)	-0.349 (0.130)	0.407 (0.139)
Travel and transportation	205.02	1.209 (0.069)	-0.297 (0.037)	0.146 (0.059)
Leisure and education	102.86	0.86 (0.082)	0.066 (0.039)	0.301 (0.061)
Other goods and services	84.51	1.232 (0.042)	-0.433 (0.039)	-0.144 (0.059)
Sum (weighted by budget share)	1000.00	1.000	0.000	0.000

Note: Computed by linear regression of expenditure of the good in question on the regressors (latent) total consumption expenditure, number of children, and number of adults from household data in the Consumer Expenditure Survey. Two-stage-least-square regression techniques were used with instruments gross income, net income, number of children, and number of adults in order to handle possible bias from the endogeneity of observed total expenditure; see the appendix for details.

By now it will be clear that the child elasticity indicates that a policy of low taxes or subsidies on food and high taxes on travel and transportation will redistribute means in the direction of equity. More specifically, such a policy will support households with many children. Table 1 suggests that since beverages and tobacco is a category with negative child elasticity, it is a good households consume less of as the number of children increases, everything else being equal. Thus, higher taxes on the category beverages and tobacco will affect households with few or no children relatively more than households with many children. The child elasticity for the clothes and shoes category is clearly positive, indicating that lower taxes given equity goals will support families with children.

The adult elasticity is an indicator that resembles the child elasticity. Similar to the child elasticity, it is a person-elasticity. It measures the change in the expenditure on a good associated with an increase in the number of adults in the household by one, relative to the average expenditure on the good per person. Table 1 reveals that food has the highest adult elasticity, above 0.7. This is larger than the child elasticity and a plausible result since an adult eats more than a child. If a household has an average purchase expenditure of magnitude 10 000 kroner on food per household member, an increase of one more adult is found in our data associated with an increase in food expenditures of magnitude 7

270 kroner, everything else being equal. The travel and transportation category has a positive adult elasticity, far below unity. It means that when the number of adults in the household increases by one, then the absolute purchase expenditure on travel and transportation is seen to increase somewhat, but not much. Average purchase expenditure on travel and transportation per household member will decrease when the number of adults increases by one. Again, policy makers that want to support large households may do so through indirect taxes by higher taxes on goods with lower adult elasticity and lower taxes on goods with higher adult elasticity.

We have argued that an increase in number of persons in a household, total purchase expenditure being the same, entails a smaller amount of total expenditure per member available for the household. In that sense the household has become poorer. This means that goods with a luxury profile, i.e. with an Engel elasticity above unity, will be substituted more than other goods will. In other words, the household spends less on luxuries. Consequently, luxury items often have negative child and adult elasticities. Necessities, on the other hand, are such that the household will dedicate more of the total purchase expenditure on the goods, even if the household has become poorer when the number of people in the household has increased and income has not. Thus, necessary goods often have positive person elasticities. This broad pattern emerges to some extent from the data. In particular, we see from Table 1 that food, leisure and education, and other goods and services follow this tendency. Those goods may be particularly interesting for policymakers, given goals of redistribution through indirect taxation.

4. Distributional Effects of Transportation Taxes

In Table 2 we present the same type of results as in Table 1, but now for detailed transportation goods. There exists one major feature in Table 2 that is essential to the argument we present. There are big indicator differences between subcategories within the same category of transportation. Consequently, a detailed knowledge of consumer behavior and indicators of disaggregated goods may yield tools for redistribution in tax policies that a general tax on a broad category could not achieve. We have summarized the distribution content of one indicator in the right-most column, in which we have ranked the transportation goods. The good with the lowest number is the most luxurious mode of transportation, as estimated from Norwegian consumer patterns. The good with the highest number is the least luxurious mode of transportation, and thus has the most distinctive characters of being a necessary good, even an inferior good.

The most luxurious modes of transportation are air flights, taxi rides, automobiles, and the concomitant road toll. Among the least luxurious modes of transportation are bicycles, buses, mopeds, and telephone. We observe also that automobile and gasoline are by far the two largest expenditure items in the transportation category. Almost six percent of total purchase expenditures are on average allocated to expenditures on cars, while almost four percent go to gasoline.

We observe that air flights are the most luxurious good in the class of transportation. It has an estimated Engel elasticity of 2, far above unity. It is a reasonable result and intuition supports the notion of higher-income households traveling more by air and spending more on air flights. Taxis are observed to have an Engel elasticity of 1.7, so taxi rides are also luxury items. In the class of "short-distance transportation", the alternatives to taxis encompass bus rides, train, mopeds, own cars (use of gasoline), and bicycles. Consumer expenditure patterns support the idea that richer households purchase the more expensive version within the class since they appear to pay for taxi rides, and increasingly so as they become richer. The high Engel elasticity of 1.6 of automobiles is no surprise. In modern society, a car is much more than a mode of transportation. It represents a life-style, it is a ticket into an identity group, and it offers more comfort as more money is spent on it. Moreover, a car is a vehicle for status signaling and richer households dedicate a relatively large share of total purchase expenditure on them. Environmentally, we know that large SUVs and luxury cars with powerful engines consume more energy per person-kilometer and pollute more per distance traveled. Thus, the luxury comes with an environmental cost. Finally, in the class of luxuries the road toll Engel elasticity estimate of 2 must be interpreted with caution. Road tolls are mostly constructed around larger cities, in which incomes also are higher. In contrast to other goods, this is thus a good not available for all households or enforced everywhere. We have not estimated road toll elasticities for road toll cities alone. It is reasonable to believe that such estimates would leave the elasticity closer to its complement, gasoline.

Necessary modes of transportation are bicycles and gasoline expenditures, with Engel elasticities of 0.9 and 0.7, respectively. Mopeds, telephone, and bus rides are even inferior goods, with Engel elasticities below zero, emphasizing the effect consisting of poor households choosing among the inexpensive class of transportation modes. Railway has an associated Engel elasticity close to 1.0, making it a good balancing on the border of the necessity/luxury dichotomy. It means that as total consumption expenditures increase, households choose to spend a proportionately equal amount on rail transportation. The same applies to the category motorcycle and scooter. However, notice the particular large standard deviations for this group.

Table 2. Indicators of Distributional Effects. Disaggregated Transportation Goods. Average 1986-1994. Standard Errors in Parentheses

Good	Budget Share	Engel elasticity	Child elasticity	Adult elasticity	Equity Engel Ranking
Motorcycle and scooter	1.36	0.955 (0.649)	-0.374 (0.529)	2.652 (0.632)	6
Air flights	7.22	2.004 (0.621)	-1.431 (0.411)	-0.441 (0.511)	1
Taxi rides	2.66	1.744 (0.249)	-1.127 (0.153)	-1.099 (0.181)	3
Railway	2.58	1.057 (0.188)	-0.745 (0.131)	0.421 (0.169)	5
Automobile	59.26	1.599 (0.175)	-0.345 (0.137)	-0.194 (0.123)	4
Gasoline and oil	39.01	0.701 (0.071)	0.022 (0.030)	0.707 (0.042)	8
Bus rides	2.95	-0.038 (0.096)	-0.085 (0.069)	1.338 (0.104)	9
Moped	0.56	-1.659 (0.487)	1.039 (0.263)	4.788 (0.429)	11
Bicycles	2.41	0.936 (0.134)	1.456 (0.204)	-0.174 (0.129)	7
Road Toll	1.30	2.003 (0.534)	-0.677 (0.315)	-0.762 (0.409)	2
Telephone	18.33	-0.104 (0.205)	0.094 (0.116)	0.376 (0.139)	10

Note: Computed by linear regression of expenditure of the good in question on the regressors (latent) total consumption expenditure, number of children, and number of adults from household data in the Consumer Expenditure Survey. Two-stage-least-square regression techniques were used with instruments gross income, net income, number of children, and number of adults in order to handle possible bias from the endogeneity of observed total expenditure; see the appendix for details.

An apparent peculiarity arises with the relative low Engel elasticity of gasoline. Its Engel elasticity is only at 0.7. Interpreted together with the high Engel elasticity of automobile there might seem to be a contradiction since gasoline and cars are close complements. However, remember that gasoline does not come with large quality variation, whereas cars do. Thus, given household composition, richer households may spend relatively more on car quality. Moreover, large expenditures on gasoline may not only reflect long trips, but also frequent trips. The problem of disentangling distance effects versus frequency effects has two features. First, for the category "commutes and short-distance transportation", purchase of gasoline may be the cheap quality good that competes with the expensive quality good taxi. Since richer households purchase the luxury edition of a good, this effect would press the Engel elasticity of gasoline down, for the category "long-distance transportation", purchase of gasoline may be the cheap quality good (in addition to time) that competes with the expensive transportation mode, air flight. Again, since richer households tend to purchase the expensive version in the class of substitutes, this effect would contribute to reduce the Engel elasticity of gasoline and contribute to separate the difference in elasticity magnitude between gasoline on the one hand and air flight and automobile on the other. Additionally, gasoline may represent the only solution to many difficult intra-household transportation problems, forcing it to be a necessity. Transportation of children, grocery shopping, and short-distance visits may be considered necessities by households, and thus be purchased as such by low-income households. This drives a wedge in between expenditures on gasoline and expenditures on automobiles, allowing poor households to spend much on gasoline but little on car quality.

The person elasticities reveal an interesting pattern. Notice that gasoline has a child elasticity of 0.02 and an adult elasticity of 0.71. Among households with equal total consumption expenditure and number of adults, an additional child will reduce the average total consumption expenditure available per member in the household. Yet, households with the additional child are observed spending more on gasoline. The effect is more pronounced for adults, holding total purchase expenditure and number of children constant, indicating that gasoline expenditures are necessary ingredients in solving the transportation needs of a household. Taxis are opposite. Given total purchase expenditure, larger households are observed with much less expenditure on that mode of transportation. Air flights follow the same pattern as taxis. Bicycles represent an altogether different pattern. Given total purchase expenditure and number of adults, households with children are observed to have much larger expenditures on bicycles than do households with fewer or no children. This does not apply to households with comparable total purchase expenditure and number of children, but with varying number of adults. They are seen to spend less on bicycles. The pattern reflects what we intuitively know. Larger households may solve their transportation needs by equipping children with bicycles.

For a policymaker with a goal of using the indirect tax system for redistributional purposes, the pattern in Table 2 yields clear advice. Higher taxes on air flights, taxis, and automobiles combined with lower taxes on mopeds, telephone, bus rides, gasoline, and bicycles will reduce inequality. Let us turn the investigation to environmental effects of such a differentiated tax system.

5. Environmental Indicators of Transportation Modes

Transportation of people entails formidable resource demands in modern society. Transportation often requires substantial amounts of energy, and the production of transportation services may involve many environmental sacrifices. Sacrifices include pollution by emission into air, water, and soil; land expropriation; noise; and scenic intrusions. There exists no consensus on how to weigh different concerns and incorporate different disamenities into an index. Yet it is clear that some modes of transportation require more energy, more resources, and more environmental disamenities per passenger-kilometer or per expenditure unit than do others. Below, we shall discuss some environmental aspects of transportation without aspiring to present the final word. We will argue that a pattern, however vague, emerges. Public transportation entails a smaller burden environmentally than do automobiles. Other private modes such as bicycle and scooter are environmentally less burdensome.

Consider the claim put forward by Button and Rietveld (1999). They say that aircraft involve high costs to society, and that public transport modes often are environmentally more benign than private motor vehicles are. However, they also warn that computation is complex and depend on a range of factors. In Table 3 some indicators are presented.

Table 3. Energy Efficiency of Transport Modes

Mode of transportation	Number of persons carried (% laden)	Energy (MJ) per passenger mile	Energy (MJ) per passenger mile (fully laden)
Petrol car, 2.0 liter	1.5	4.96	0.87
Intercity rail	338 (60%)	0.77	0.46
Express coach	30 (65%)	0.61	0.40
Air, Boeing 737	100 (60%)	3.90	2.34
Motorcycle	1.2	3.13	1.80
Moped	1	1.31	1.31
Bicycle	1	0.10	0.10

Source: Huges (1990).

From Table 3 we may acquire a broad picture. Cars and aircraft use much energy per passenger-mile. Public transportation, mopeds, and bicycles do not. Energy use is correlated with direct emission discharges and indirect pollution and environmental disamenities in energy generation.

Energy usage is of course only one aspect. Physical area is another. Ships and airplanes do not require much space while in flight, but harbors and airports do. Moreover, connecting transportation adds to the total amount of area and energy used. Cars and buses require roads. The roads must be in close proximity to urban centers and residences, and they come at high costs. Moreover, time costs should be considered. These aspects are not incorporated in Table 3.

In Table 4 we present more detailed results on transport modes. We observe that indicators are sensitive to choice of vehicle make, age, distance, and load. Time use is not included, neither are disamenities such as scenic intrusion, noise, or accidents. The picture confirms that motorized vehicles are environmentally friendly when many passengers share it and when they are on ground. Cars and aircraft use much energy and pollute. The table seems to support such schemes as car share and public transport network.

Table 4. Energy Usage (kWh/pkm) and Emission to Air (g/pkm) for Main Trip for Several Transport Modes

Mode of transportation	Load (person/car, % of capacity)	Energy (kWh/pkm)	CO_2 (g)	SO_2 (g)	NO_x (g)	CO (g)	CH_4 (g)	NMVOC (g)	Particles (g)
Petrol car	2.2(normal)	0.25	65	0.013	0.130	0.360	0.0040	0.030	0.007
Petrol car	3	0.17	43	0.009	0.086	0.238	0.0026	0.020	0.005
Taxi	1.5(normal)	0.33	87	0.030	0.127	0.206	0.0012	0.020	0.015
Bus	50 (normal)	0.15	36	0.017	0.450	0.117	0.0009	0.036	0.031
Rail (Inter-City)	38 (normal)	0.14	0	0	0	0	0	0	0
Rail (Local)	35 (normal)	0.14	0	0	0	0	0	0	0
Rail (Express)	48 (normal)	0.11	0	0	0	0	0	0	0
Air, Boeing 734/735. Distance: 400km	65	0.72	191	0.060	0.517	0.412	0.0009	0.018	0.023
Air, Boeing 734/735. Distance: 950km	65	0.60	158	0.051	0.465	0.331	0.0005	0.014	0.020

Source: Andersen (2001, tables 3, 5, 12, and 13)

Table 5. Emissions to Air in Norway due to Households Transport Consumption, per Expenditure in Consumer Prices. Ton per million NOK. Norway 1993

Commodity group	CH4	CO2	N20	CO2-eq.	NOX	NH3	SO2	*Acid-eq.*
Privat transport	*0,106*	*120,025*	*0,008*	*124,710*	*0,872*	*0,010*	*0,034*	*0,021*
Automobiles	0,021	1,516	0,000	2,043	0,010	0,000	0,002	*0,000*
Motor cycles and bicycles	0,026	2,822	0,001	3,749	0,013	0,001	0,004	*0,000*
Spare parts, tyres etc	0,014	2,899	0,001	3,447	0,009	0,000	0,005	*0,000*
Petrol and oils	0,170	281,185	0,018	290,276	2,041	0,022	0,074	*0,048*
Insurance and repairs	0,065	3,643	0,001	5,283	0,023	0,001	0,004	*0,001*
Repair shop services	0,192	12,532	0,002	17,233	0,088	0,002	0,012	*0,002*
Other services	0,117	17,389	0,002	20,578	0,160	0,003	0,019	*0,004*
Public transport	*0,095*	*88,320*	*0,005*	*91,744*	*1,094*	*0,003*	*0,113*	*0,027*
Local	0,098	142,178	0,006	145,950	1,946	0,003	0,132	*0,047*
Long distance	0,084	77,957	0,005	81,244	0,858	0,002	0,161	*0,024*
Moving expenses and freight	0,103	74,577	0,005	78,266	0,779	0,002	0,058	*0,019*
Package tours	0,104	39,717	0,003	42,896	0,403	0,003	0,041	*0,010*
All household consumption	0,375	12,479	0,015	25,082	0,111	0,036	0,016	*0,005*

In Statistics Norway there is an ongoing project connecting national accounts and emission statistics, see Sørensen et al. (2001, 2002). A supply and use table with ca 170 industries and more than 1000 products is a core part of the Norwegian national accounts system. From this is derived a quadratic input-output model with ca 50 sectors, which is inverted in order to calculate the indirect effects of changes in consumption. The system of emission statistics used is described in Flugsrud et al (2000). Based on this total system, we have calculated the direct and indirect emission from household transport consumption in Norway. See Wier et al. (2001) for a somewhat similar input-output study of the Danish economy, and references to other studies. We have divided the emissions connected to each commodity group by the consumer expenditure on this group. Thus, we obtain emission intensities, i.e. emission per krone. Our results are presented in Table 5.

These results per monetary unit support the results above per passenger kilometer. The use of petrol and oils in private transportation has the largest emission intensities. Note that automobiles have very low emission intensities since (i) these are not produced in Norway and we do not include emissions in the countries exporting cars and (ii) a large part of the consumer price consists of indirect taxes. This point reduces the emission intensities for the aggregated group private transport, but still private transport has substantially larger emission intensities than public transport. Local public transport has rather large emission intensities, either due to high emissions per passenger kilometer or low (subsidized) price per passenger kilometer. Long distance public transport includes both emission intensive modes like air planes and low emission modes like railway. Thus, it would be valuable to obtain results on a more detailed grouping of public transport in future studies based on this type of data.

6. Concluding Remarks and Policy Implications

Some environmental taxes levied on specific consumer goods lead to a more equal distribution of material standards of living. Other environmental taxes entail more unequal distribution. But a differentiated, empirically based tax system may attain both environmental targets and distributional goals. Higher taxes on air flights, taxis, and automobiles together with lower taxes on bus rides, bicycles, and mopeds have both favorable environmental effects and reduce inequality. Taxes on gasoline may correct for adverse environmental effects, but they contribute somewhat to inequality. Railway passenger transportation seems to be neutral, distributionally, since the Engel elasticity is estimated close to unity.

These results follow from an empirical investigation of environmental and distributional effects of taxation. From the consumer expenditure surveys there emerge a pattern of consumer choice within the class of transportation. There is a regularity of richer households choosing the more expensive mode of transportation among substitutes and poorer households choosing the less expensive modes. Moreover, since the more expensive modes also lead to more pollution and energy-consumption per person-kilometer and less expensive modes lead to less pollution and energy-consumption, we observe that at least on some environmental indicators the transportation choices made by richer households pollute more given transportation goals than choices made by poorer households. Thus, differentiating the indirect tax system to account for the environmental effects will at the same time reduce inequality. Gasoline is the exception, in which environmental and distributional effects of the tax system oppose each other.

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Consumption Data and Empirical Methods

We use observations on household purchase expenditures from the Norwegian Consumer Expenditure Surveys in the period from 1986 to 1994, see Statistics Norway (1990, 1993, 1996). The surveys are conducted continuously by Statistics Norway. Every 14-day period of the year, 1/26 of households report their purchase expenditures. Sample sizes are typically around 1200 households per year. The sampling scheme is a two-stage stratified random sample. Response rates vary around 60 percent. The commodities are classified into about 800 different items when coding the expenditures in the households accounting books. Standard aggregation levels are 9, 37, 150 and 488 commodity groups.

In order to analyze the effects of taxation on inequality it is important to define in some way who are rich and who are poor. We characterize a household by three variables: (latent) total consumption expenditure, the number of children and the number of adults. The term 'richer' is defined by the following partial ordering of households: (i) a household is richer the larger total consumption expenditure is, given the number of children and adults; (ii) a household is richer the smaller the number of children is, given total consumption expenditure and the number of adults; (iii) a household is richer the smaller the number of adults is, given total consumption expenditure and the number of children. The term 'poorer' is defined correspondingly. By assuming that expenditures on each commodity are linear functions of total consumption expenditure, the number of children and the number of adults in the household, we can derive very strong robustness results on the ranking of commodities if the policy maker wants to support poor versus rich households when deciding the structure of indirect taxes. The ranking of commodities according to the Engel, child and adult elasticities for the average household in the population, summarizes the most important information on the distributional effects of indirect taxes for the three dimensions of rich and poor mentioned above in the whole population. See Aasness and Røed Larsen (2002) for detailed theoretical results.

In line with Occam's razor we choose such linear Engel functions also in our empirical analyses. Although this is a simplification considered as a realistic description of demand patterns, the empirical results on the ranking of commodities according to effects on the distributional effects of commodity taxes may well be robust to the choice of functional form.

The concept of total consumption expenditure from consumer theory, used to classify rich and poor, can be interpreted closely to the term permanent income in Friedman (1957). This concept is considered as a latent variable, and we use observed total expenditure as an indicator and income as an instrument for this basic latent variable under estimation. See Aasness (1990, Essay 5 and 6) and Aasness, Biørn and Skjerpen (1993) for econometric theory, model and analyses using this type of approach. The econometric model in Aasness, Biørn and Skjerpen (1993) is more elaborated and is identified and estimated using panel data on all commodities simultaneously. However, we can derive from it the more simple econometric model used in this paper, as a reduced form which can be estimated by using a single equation method on cross section data. Single equation estimation on each commodity separately fulfills automatically adding-up restrictions, cf. the adding-up results in Table 1. Nicholson (1957) first proved this type in a somewhat similar case without instrumental variables. Wangen and Aasness (2001, Appendix B) proved adding-up results for the same type of model as used in this paper estimated by instrumental variables.

We estimated the regressions separately on the cross-section for each year in the period 1986-1994, using the SYSLIN procedure in SAS, employing the 2SLS-technique with the following instrumental variables: gross income, net income, number of children and number of adults. A preliminary analysis showed few time trends in the elasticities, and we simply used the weighted arithmetic mean of the elasticities over the 9 years, using yearly budget shares as weights. The budget shares in Tables 1 and 2 are unweighted means of budget share in each year. The standard errors in Tables 1 and 2 were estimated by the Stderr in the Proc means procedure in SAS, based on standard procedure for estimating standard errors for weighted means. This demands few assumptions from the underlying microeconometric model. If we accept stronger assumptions on the residual distributions in the microeconometric model, we can use the standard errors from the SYSLIN program. Preliminary analysis showed that these estimates of standard errors were of comparable size, and we preferred to use the simple method demanding the fewest assumptions.

The Engel elasticity for each year was computed as the ratio between the estimated total consumption regression coefficient and the budget share for the good in question. The budget share is defined as the mean purchase expenditure on the good over households divided by the mean total purchase expenditure on all goods over households. The child elasticity is computed as the ratio between the estimated regression coefficient of the purchase expenditure effect from the number of children in the household and the mean purchase expenditure on the good per person. Similarly, the adult elasticity uses the estimated regression coefficient of the purchase expenditure effect from number of adults in the household as numerator and mean purchase expenditure on the good per person in the household as denominator. See Aasness and Røed Larsen (2002) for more details.